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HYDROPOLL, Inc.

Suite B, 731 S. Durkin Drive
Springfield, Illinois 62704

Phone (217) 793-1361

ASSESSMENT OF SEMI-ANNUALLY
COLLECTED GROUNDWATER SAMPLES
RCRA IMPOUNDMENT
CABOT CORPORATION PLANT
TUSCOLA, ILLINOIS

(U.S. EPA I.D. No. ILD042075333)

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Prepared by: Rauf Piskin, Ph.D., C.P.G.

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ASSESSMENT OF SEMI-ANNUALLY COLLECTED GROUNDWATER SAMPLES

INTRODUCTION

This report is the semi-annual assessment of groundwater quality for the hazardous waste impoundment at the Cabot Corporation plant near Tuscola, Illinois. The report has been prepared to satisfy the requirements of Section 725. 193(d) (5), Subpart F: Groundwater Monitoring.

Groundwater quality assessment reports are to be prepared as indicated in "Groundwater Quality Assessment Program at Cabot Corporation Plant, Tuscola, Illinois", as amended. The assessment program had been prepared to satisfy the requirements of Section 725. 193(d) (2) and submitted to IEPA in February 1984. In the supplements to the assessment program, the hazardous waste constituents to be analyzed were identified, the number of wells in the monitoring system were modified, and a new schedule of sampling and analysis were established. These modifications were approved by the IEPA.

The purpose of this report is to assess the rate and extent of migration and the concentration of hazardous waste constituents in the groundwater beneath the plant property in vertical and horizontal directions based on the semi-annual sampling.

Monitoring System

As approved by the IEPA, nine wells out of thirteen make up the monitoring system for the impoundment at the Cabot plant (Figure 1). Of these, MW-1 (G101) is the background well and the rest are downgradient. MW-9 (G109) and MW-13 (G113) are the deep monitoring wells which are installed to assess vertical migration of hazardous waste constituents.

Hazardous Waste Constituents

Four hazardous waste constituents were identified in the groundwater samples from the monitoring wells in the plant property. These constituents are:

Bis (2-Ethyl-Hexyl) Phthalate
Carbon Tetrachloride
Tetrachloroethylene
Methylene Chloride

Parameters Analyzed and Assessment Methods

The semi-annual samples were collected from the monitoring wells in April and May, 1984. These samples were analyzed for both the four hazardous waste constituents and the indicator parameters of groundwater contamination. The results of the analyses were submitted to the IEPA on May 24, 1984. The results are also summarized in Tables 2 and 3.

Hazardous Waste Constituents

Comparisons of the analysis results from the downgradient wells with those from the upgradient well will be made to determine whether the hazardous waste constituents have entered groundwater from the impoundment. The chemical analysis results and velocity calculations based on a modified Darcy's formula will be utilized to estimate the extent of migration of the hazardous waste constituents. The rate of groundwater flow from the impoundment and at the eastern property of the plant property will be estimated from the Darcy's formula.

Indicator Parameters of Groundwater Pollution

The means for each indicator parameter were calculated. These means were compared with their corresponding initial background means using the Student's t-test at the 0.01 level of significance to determine statistically significant increases in the case of pH decreases. Each well sampled for the semi-annual assessment considered individually and were compared with the initial background means of the upgradient well (G101).

Student's t-Distribution

The value of Student's t-distribution with n-1 degrees of freedom is expressed by the following equations (Alder and Roessler, 1964):

$$t = \frac{\bar{X} - m}{Sx} \qquad \text{where,} \qquad (1)$$

$$Sx = \frac{s}{n} \qquad (2)$$

t = value of t for n-1 degrees of freedom

$\bar{X}$ = mean of the measurement, it is the mean of the semi-annual analysis in this case,

m = mean of the sample, it is the mean of the background in this case,

s = best estimate of the standard deviation of the sample where $n \leq 30$, it is the standard deviation calculated for the background in this case,

Sx = best estimate of the standard deviation of the mean of samples,

n = number of variates in a sample, it was 16 of initial background,

Vf = degree of freedom; it is n-1 or 15.

Calculation of t Values for Indicator Parameters

Utilizing the above equations, t values are calculated for specific conductance as below:

S = 47.53 (Table 3)

m = 1361 (Table 3)

$$Sx = \frac{S}{\sqrt{n}} = \frac{47.53}{\sqrt{16}} = \frac{47.53}{4} = 11.88$$

$$t = \frac{\bar{X}-m}{Sx} = \frac{\bar{X}-1361}{11.88}$$

Place, $\bar{X}$, mean conductance values measured semi-annually (Table 3) into the above equation and solve for t.

The calculated t values are listed in Table 4. The value of t 0.01 for Vf = 15, taken from statistical tables, is also included in Table 4. Similarly, t values have been calculated from the equations (1) and (2) for TOC, TOX, and pH. These calculated values and their corresponding t 0.01 values from statistical tables are also shown in Table 4.

ASSESSMENT

Hazardous Waste Constituents in Groundwater

Review of the analysis results in Table 2 indicates that three of the four hazardous waste constituents were measurable and have entered groundwater. The analyzed parameters were below their respective detection limits in the background well (G101) while measurable levels were found in the immediately downgradient wells (G106, G107, and G108) from the impoundment. This indicates that the hazardous waste constituents have primarily ? migrated from the impoundment. However, the concentrations were low, in ppb level, in the mentioned downgradient wells, except those of tetrachloroethylene which were between 0.43 and 2.4 mg/l. Tetrachloroethylene was also measured as 64 ppb in well G109.

Rate and Extent of Migration of Hazardous Waste Constituents

Review of the analysis results in Table 2 in conjunction with the location of shallow monitoring wells (Figure 1) shows that one or two of the hazardous waste constituents were above their detection limits in the monitoring wells (G106, G107, and G108) which are immediately downgradient from the impoundment. All four parameters were below their detection limits in recently drilled three shallow monitoring wells (G110, G111, and G112).

Although these analysis do not indicate the extent of contamination (or the location of the contamination front), they show that the groundwater contamination occured primarily near the impoundment in the downgradient direction. The groundwater along the northern half of the eastern boundary of the plant has not been contaminated.

The extent of the migration has been determined from the Darcy's formula. When the groundwater samples were collected for the first quarter, the elevation of groundwater was measured in the monitoring system wells (Table 1). Based on the elevations taken from the shallow wells, a potentiometric map has been prepared (Figure 1), and the direction of regional groundwater flow has been estimated from elevations in MW-1 (G101), MW-11 (G111), and MW-12 (G112). The regional flow direction is towards [redacted] and the hydraulic gradient is 0.007 in the unaffected areas. Based on the groundwater elevation data taken from the eight monitoring wells on January 4 and 6, 1983, the regional flow direction had been estimated towards [redacted] (Figure 2), which is somewhat different than the present direction.

Migration of waste fluid has changed groundwater elevations, general flow direction, and the hydraulic gradient near the impoundment. A groundwater mound formed beneath the impoundment. From Figure 2, it is estimated that the distortion of groundwater contours occurred to a distance of 250 ft in the regional flow direction from the impoundment. The hydraulic gradient averages 0.024 in this affected area.

Groundwater Velocity and Extent of Contamination in Horizontal Direction

The horizontal component of the velocity of the groundwater flow through the glacial till (silty clay) can be estimated using a modified version of the Darcy's equation as below:

$$V_H = K \frac{dh}{dl} \frac{1}{n} \quad \text{, where}$$

V_H = Velocity , ft/yr

*K_F = Field hydraulic conductivity

= 6×10^{-5} cm/sec (62.1 ft/yr), (reported previously)

$\frac{dh}{dl}$ = Hydraulic gradient,

n = Effective porosity (assumed 0.05) ?

The hydraulic gradient in an area unaffected by the impoundment was estimated as 0.007 from Figure 2. Thus, the groundwater velocity is calculated from the above equation as 8.69 ft/yr in this area using K_F.

From a perspective of migration of contaminant, the most important part of the impoundment to consider is the part of the plant property immediately downgradient from the eastern berm of the impoundment. The hydraulic gradient averages 0.024 in the distorted (affected) area. Using the same equation above, the average

* The calculations below were made using only field hydraulic conductivity. If the laboratory hydraulic conductivity was used, results would have been about four order of magnitude smaller. ?

velocity is calculated as 29.8 ft/yr. That means it would take 8.4 years for a drop of fluid to travel from the impoundment to a point 250 ft away in the regional flow direction. Since the impoundment has been there for seventeen years, since 1966, and a fluid drop from the impoundment would travel a 250 ft distance in 8.4 years; thus, there is a time period of 8.6 years to travel beyond the 250 ft distance from the northeast corner of the impoundment in the unaffected area. Because the velocity of groundwater is calculated as 8.69 ft/yr in the unaffected area, a drop of fluid from the impoundment would travel 74.7 ft in 8.6 years beyond the affected area.

Thus, it seems that the fluid that migrated from the impoundment in 1966 would travel approximately a distance of 325 ft in the regional flow direction. The potentiometric surface maps in Figures 1 and 2 suggest that the travel distance would be shorter than the calculated 325 ft in other directions.

In the calculation of 325 ft, it is assumed that there is no other potential contamination sources. However, a small landfill and leachfield exist on east of the impoundment approximately 200 ft and 550 ft away, respectively. Any fluid contribution from these sources would affect the flow direction and the calculated distance.

<u>Groundwater Velocity and Contamination in Vertical Direction</u>

The water elevation data in Table 1 for two pairs of monitoring wells (MW-6/MW-9 and MW-10/MW-13) indicate that the groundwater beneath the plant property migrates downward. Furthermore, the chemical analysis data in Table 2 suggest a slight contamination of relatively deeper groundwater by tetracholoroethylene in MW-9 (G109) which is 52.5 ft deep. However, the deeper groundwater in MW-13 (G113), located at the eastern boundary of the plant property, has not been contaminated.

The vertical component of the groundwater velocity was estimated by using a modified Darcy's equation and data from these wells. It is assumed that K is constant in horizontal and vertical directions. The modified equation is:

$$V_V = K \frac{dh}{dl} \frac{1}{n} \quad \text{where,}$$

$\frac{dh}{dl} = 0.663$ for the MW-6/MW-9 pair, and

$\frac{dh}{dl} = 0.165$ for the MW-10/MW-13 pair.

(Other terms expressed before)

Using K_F, V_V would be:

$V_V = 62.1$ ft/yr x $0.663 \times \frac{1}{0.05} = 823$ ft/yr at MW-6/MW-9, and

$V_V = 62.1$ ft/yr x $0.165 \times \frac{1}{0.05} = 188$ ft/yr at MW-10/MW-13.

If K_L, laboratory measured hydraulic conductivity, (8.3×10^{-9} cm/sec or 8.6×10^{-3} ft/yr), is used, V_V would be:

$V_V = 8.6 \times 10^{-3}$ ft/yr x $0.663 \times \frac{1}{0.05} = 0.11$ ft/yr at MW-6/MW-9 and,

$V_V = 8.6 \times 10^{-3}$ ft/yr x $0.165 \times \frac{1}{0.05} = 0.03$ ft/yr at MW-10/MW-13.

It is clear that the calculated vertical velocity of groundwater is higher than the calculated horizontal velocity. Furthermore, the vertical velocity is higher near the impoundment. This is probably due to higher hydraulic gradient resulting from the groundwater mound under the impoundment.

However, the calculated velocities in the vertical direction seem to be higher for K_F and lower for K_L than it would be expected. This is probably due to both differences between K_F and K_L and to the assumption made that K was equal in horizontal and vertical directions. The value of K should be lower with depth due to compaction and lack of weathering. If it is assumed that the contaminants reached to 52 ft depth in MW-9 in seventeen years, V_V is calculated to be 3 ft/yr. At this velocity, K would be about 2.6×10^{-7} cm/sec (0.27 ft/yr) which is probably the average hydraulic conductivity of the till in vertical direction and more reasonable than K_L. Thus, the 3 ft/yr vertical velocity near the impoundment seems to be reasonable, too.

Using $K = 2.6 \times 10^{-7}$ cm/sec, the velocity of groundwater in vertical direction at the location of MW-10/MW-13 is calculated as 2.3 ft/yr.

Rate of Discharge from the Impoundment

Under saturated conditions, the volume of discharge from the bottom of the impoundment can be calculated using the Darcy's formula. The discharge has been calculated in two ways by using the hydraulic conductivity measured in the laboratory and in the field. The Darcy's formula is:

$Q = K \frac{dh}{dI} A$ where,

Q = Volume of discharge, ft^3/yr

$\frac{dh}{dl}$ = Hydraulic gradient = 0.024 in the affected area

A = Area of the impoundment = 34,000 ft^2

K_F = Field hydraulic conductivity = 6×10^{-5} cm/sec
= 62.1 ft/yr

K_L = Laboratory hydraulic conductivity = 8.3×10^{-9} cm/sec
= 8.6×10^{-3} ft/yr

When the above values introduced into the formula,

$Q_F = 62.1 \text{ ft/yr} \times 0.024 \times 34{,}000 \text{ ft}^2 = 50{,}674 \text{ ft}^3\text{/yr}$
= 379,039 gallon/yr

$Q_L = 8.6 \times 10^{-3} \text{ ft/yr} \times 0.024 \times 34{,}000 \text{ ft}^2 = 7.02 \text{ ft}^3\text{/yr}$
= 52.5 gallon/yr

The great difference between the Q_F and Q_L is due to the difference of about four order of magnitude between K_L and K_F.

Rate of Discharge at the Property Boundary

The Darcy's formula is used to estimate this rate. The estimate was made for a unit length, let's say 100 ft, and a 30-ft saturated thickness. The hydraulic gradient is approximately 0.007 near the boundary. K_F, field conductivity, is used in calculations.

The Darcy's formula is:

$$Q = K_F \frac{dh}{dl} A \quad \text{where,}$$

$$A = 100 \text{ ft} \times 30 \text{ ft} = 3{,}000 \text{ ft}^2$$

$$Q = 62.1 \text{ ft/yr} \times 0.007 \times 3{,}000 \text{ ft}^2 = 1{,}304.1 \text{ ft}^3\text{/yr}$$

$$= 9{,}755 \text{ gallons/yr}$$

Thus, the estimated volume of groundwater flow is 9,755 gallons per year through the upper 30 ft of the saturated zone of the till and along the 100-ft length of the property boundary.

Indicator Parameters

Comparison of the calculated t values of the indicator parameters of groundwater contamination with the published t values at the 0.01 level of significance indicate that the hazardous waste impoundment has been leaking. The waste fluid leaked from the impoundment is contributed to the underlying groundwater.

Only pH and TOX show a significant change at G101 (Table 4). These changes in the background well are caused by an outside source located at the west, upgradient from the well. All the indicator parameters change significantly at the downgradient wells, G106, G107, and G108, located very closely to the impoundment. Conductance, TOC and TOX increased significantly while pH decreased significantly. The impoundment is the primary source of the significant changes in groundwater in the vicinity of the impoundment.

The potentiometric map (Figure 1) indicates that the three wells could be affected by the impoundment. The conclusion reached from the statistical analyses above are in agreement with the water level measurements, which shows a groundwater mound and migration of waste fluids from the impoundment.

RECOMMENDATIONS

1. Water levels in all monitoring wells should be measured prior to the sampling for the next quarter. The regional flow direction should be determined from this data to confirm either the direction calculated in this report or the previously reported directions.

2. During the next quarterly sampling, water in G109 and G113, deeper wells, should be completely evacuated before sampling. The sampling equipment should be cleaned carefully to prevent any cross contamination.

3. The next quarterly samples should be collected from the monitoring system wells in early July, 1984.

Prepared by;

Rauf Piskin

Rauf Piskin, C.P.G. 5090
Hydrogeologist

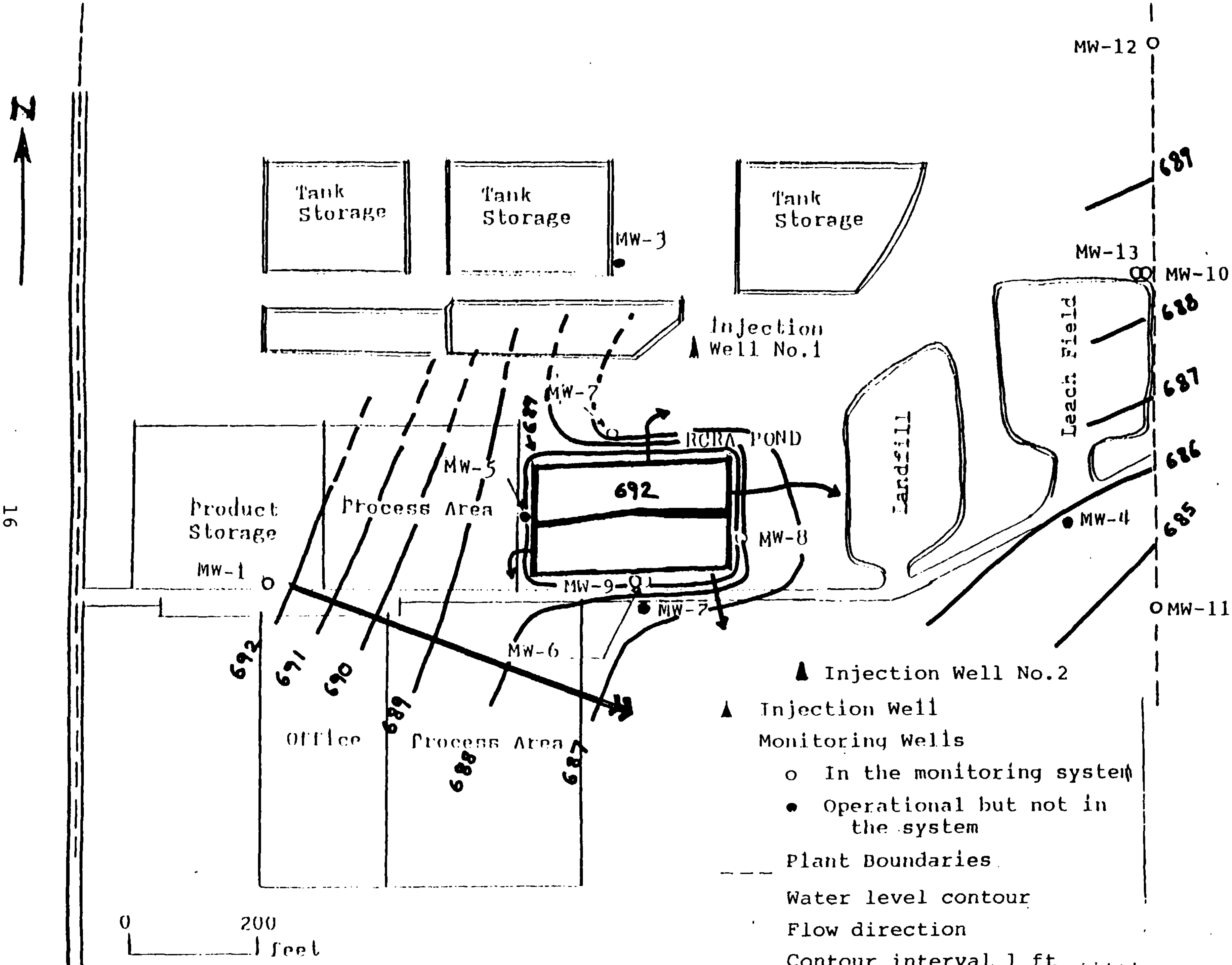

Figure 1. Potentiometric map based on the first quarter's water level elevations

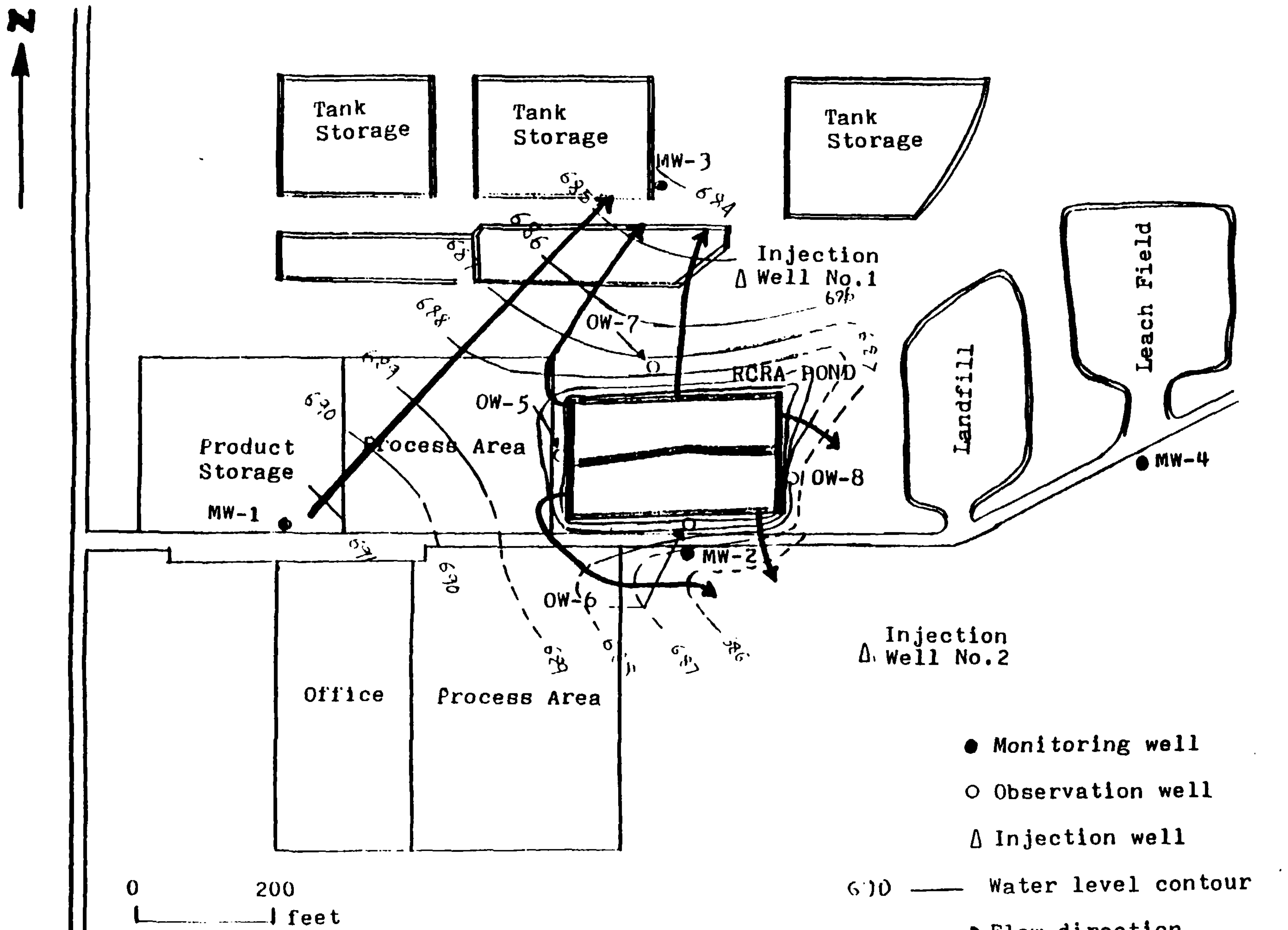

Figure 2. Potentiometric map based on water level elevations taken on January 4-6,1983(from Hydropoll, Inc., 1984, Assessment of semi-annually collected groundwater samples RCRA Impoundment, Cabot Corporation plant, Tuscola, Illinois)

Table 1. Depth to and elevation of water levels in the monitoring system wells of the Cabot Plant

WELL NUMBER	Ground Elevation, Ft	MEASUREMENT			Level difference in paired wells, ft
		Depth to Water, Ft	Elevation of * water level, Ft	Measurement Date	
MW -1	693.44	0.75	692.69	4/3/84	
MW -6	691.84	2.00	689.84	4/3/84	13.59
MW -9	691.59	15.34	676.25	4/27/84	
MW -7	690.60	3.83	686.77	4/4/84	
MW -8	691.14	3.17	687.97	4/4/84	
MW -10	689.66	0.92	688.74	4/25/84	5.69
MW -13	689.05	6.00	683.05	4/26/84	
MW -11	686.64	2.40	684.24	4/25/84	
MW -12	690.97	1.58	689.39	4/25/84	

* Water elevation is above MSL

Table 2. Concentration of hazardous waste constituents in the groundwater samples from the monitoring wells, Cabot Corporation plant, Tuscola, Illinois

	G101	G106	G107	G108	G109	G110	G111	G112	G113
Collection Date	4/3/84	4/3/84	4/4/84	4/4/84	4/27/84	4/25/84	4/25/84	4/25/84	4/26/84
Carbon Tetra Chloride UG/L	<1	<1	<1	180	<1	<1	<1	<1	<1
Methylene Chloride UG/L	<1	250	<1	<1	<1	<1	<1	<1	<1
Tetrachloroethylene UG/l	<1	2400	430	1540	64	<1	<1	<1	<1
Bis (2-Ethyl-Hexyl) Phthalate UG/l	<10	<10	<10	<10	<10	<10	<10	<10	<10

Table 3. Initial background, and measured values, arithmetic means (X), variances and standard deviations of groundwater contamination indicator parameters of semi-annually collected groundwater samples on May 9, 1984

Parameter		MW-1 (G101) (Initial Background)	G101	G106	G107	G108
ph, unit	1st measurement		8.03	1.96	5.83	2.12
	2nd measurement		8.03	1.97	5.84	2.12
	3rd measurement		8.02	1.97	5.84	2.12
	4th measurement		8.03	1.96	5.84	2.12
	Mean	7.34	8.0275	1.9666667	5.8366667	2.12
	Variance	0.0058	0.0000188	0.0000222	0.0000222	0.
	Standard deviation	0.076	0.005	0.0057735	0.0057736	0.
Conductivity Nmhos/cm	1st measurement		743.	59400.	51600.	53000.
	2nd measurement		746.	59100.	51600.	53000.
	3rd measurement		743.	59400.	53000.	53000.
	4th measurement		743.	59100.	51600.	53000.
	Mean	1360.62	743.75	59250.	51525.	53000.
	Variance	2259.58	1.6875	22500.	16875.	0.
	Standard deviation	47.53	1.5	173.20508	150.	0.
TOC, mg/l	1st measurement		7.3	105.	38.	104.
	2nd measurement		5.5	101.	38.	109.
	3rd measurement		5.4	102.	35.	110.
	4th measurement		7.7	104.	37.	110.
	Mean	13.9875	6.475	103.	37.	108.25
	Variance	22.2145	1.071875	2.5	1.5	6.1875
	Standard deviation	4.71	1.1954776	1.8257419	1.4142136	2.872281
TOX, mg/l	1st measurement		0.101	8.740	2.680	4.610
	2nd measurement		0.092	8.260	2.500	3.710
	3rd measurement		0.093	8.730	3.310	4.590
	4th measurement		0.091	8.200	2.750	3.880
	Mean	0.051875	0.09425	8.4825	2.81	4.1975
	Variance	0.0005097	0.0000157	0.0642188	0.09165	0.165668
	Standard deviation	0.023	0.0045735	0.2926175	0.3495712	0.469991

Table 4. Calculated t values of indicator parameters of groundwater contamination, and comparison with their t 0.01 values published, the Cabot Corporation plant Tuscola, Illinois.

Monitoring Well No.	pH		Conductivity		TOC		TOX	
	Calculated (t)	t0.01 = 2.947	Calculated (t)	t0.01 = 2.602	Calculated (t)	t0.01 = 2.602	Calculated (t)	t0.01 = 2.602
G101	36.2	Increase	- 51.94		- 6.37		7.35	Increase
G106	-283.	Decrease	4873.	Increase	75.43	Increase	1466.	Increase
G107	- 79.1	Decrease	4223.	Increase	19.50	Increase	480.	Increase
G108	-275.	Decrease	4347.	Increase	79.88	Increase	721.	Increase

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Cabot plant files